NWC TP 6761

Kevlar Stitch Patterns

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SEPTEMBER 1986

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Naval Weapons Center

FOREWORD

The research described in this report was performed between fiscal years 1983 and 1986. The work was supported by NAVAIR Task No. WF41451, program element 62241N, through the Naval Air Development Center, Warminster, PA.

This is the final report of the Kevlar stitch seam pattern efficiency study performed under the Kevlar Material Evaluation project. The report does not constitute an endorsement by the Naval Weapons Center of any commercial product.

This report was reviewed for technical accuracy by A. Karrer.

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11 September 1986

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Released for publication by
G. R. SCHIEFER
Technical Director

NWC Technical Publication 6761

Published by .... Technical Information Department
Collation .... Cover, 13 leaves
First printing .... 120 copies

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A176783

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT A Statement
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NWC TP 6761	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Weapons Center 6b. OFFICE SYMBOL *(If applicable)*	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS *(City, State, and ZIP Code)* China Lake, CA 93555-6001	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Weapons Center 8b. OFFICE SYMBOL *(If applicable)*	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS *(City, State, and ZIP Code)* China Lake, CA 93555-6001	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO: 62241N PROJECT NO: TASK NO: WF41451 WORK UNIT NO:

11. TITLE *(Include Security Classification)*

KEVLAR STITCH PATTERNS

12. PERSONAL AUTHOR(S)
Tubis, R. I.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM 1983 TO 1986	1986, September	23

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*

Parachute Design, Kevlar Textile Materials

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

(U) The results of a study of parachute design Kevlar stitch pattern efficiency are given (1) to serve as a foundation for future studies of parachute stitch seam efficiencies, and (2) to eliminate the need for project personnel to perform individual pattern efficiency studies for each project.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☒ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL R. I. Tubis	22b. TELEPHONE *(Include Area Code)*: (619) 939-2377 22c. OFFICE SYMBOL: Code 64331

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

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INTRODUCTION

The goal of this study was to reduce or eliminate the need for parachute design project personnel to perform separate, individual stitch seam pattern efficiency studies for each project. This report is intended to serve as a resource for parachute design personnel using Kevlar textile materials and as a foundation for anyone investigating the seam efficiencies of Kevlar for stitch patterns.

Kevlar became commercially available in the early 1970s. Since then it has been used in tire cords, composites, and parachute fabrics, cords, tapes, and threads. However, no reports or handbooks of Kevlar stitch patterns and their efficiencies have been published, as has been done for nylon (Reference 1). Because of this lack of documentation, each design project has been forced to do its own stitch pattern efficiency study. Limited amounts of seam efficiency information obtained in this fashion were published. This information was usually incomplete, duplicated other efforts, and dealt only with the areas of interest. This study into parachute stitch seam efficiencies was performed in order to eliminate some of this duplication and to give a good foundation for future studies.

SUMMARY

The seam efficiencies of many stitch patterns using Kevlar fabric, cords, tapes, and threads were determined. The highest seam efficiencies for each material were as follows:

1. Cord—double Chinese finger, 98%
2. Fabric—four rows, straight stitch flat fell seam, 70%
3. Tapes—4- and 5-point diamond and horizontal diamond, 100%

Other stitch patterns were tested, including box stitch, double W, and single and double throw zigzag.

TEST EQUIPMENT

The following equipment was used in this study:

1. Model 1115 Instron Universal Testing Instrument
2. Instron Microcon II Data Computer
3. Digital Equipment Corporation VAX 11780 Minicomputer

TEST MATERIALS

The following Kevlar 29 textile materials were used:

1. MIL-T-87128 E thread, 25-lb break strength
2. MIL-T-87128 F thread, 35-lb break strength
3. MIL-T-87128 FF thread, 60-lb break strength
4. MIL-T-87128 3 cord, 80-lb break strength
5. MIL-C-87129, type VII cord, 1000-lb break strength
6. MIL-C-87129, type X cord, 3500-lb break strength
7. MIL-T-87130, type VI, class 5 tape, 1500-lb break strength
8. MIL-T-87130, type XI, class 9A tape, 1000-lb break strength
9. MIL-C-87156, type II cloth, 2.25 oz/yd^2
10. 2.0 oz/yd^2 Kevlar cloth similar to item 9 above

TEST METHOD

The procedure used was Federal Test Method Standard 191C, Method 5110. Since this method is only for fabric samples and no other Federal test method was available for testing the seam efficiencies in cords and tapes, the Method 5110 procedure was also used for cord and tape testing. The approach taken was to make and test the stitch patterns as the patterns would be produced under production environment and not the "perfect" laboratory environment. We wanted the results to be realistic for everyday use.

The only deviations were as follows:

1. The number of stitches per inch was eight instead of 12.
2. The stitch patterns were inspected only to ensure normal construction, not for perfect construction.
3. Different length stitch patterns were used to determine the minimum length for maximum efficiency.

RESULTS AND DISCUSSION

Three main areas of stitch seam patterns are being studied for Kevlar in parachute applications:

1. Overlap and flat fell fabric seams
2. Webbing-to-webbing seams
3. Cord-to-cord seams

This study was not meant to cover all areas or even the above areas completely. We were only trying to lay a solid foundation.

FABRIC SEAMS

The two seam types studied were the flat fell (LSa) and the overlap (LSc and modified LSc) seams (Reference 2). The latter is used exclusively throughout the parachute canopy, while the former is not used at all in parachute canopy construction because of its weakness. The overlap seam type is added strictly as a comparison or control, since it is the simplest seam. The modified LSc type seam uses zigzag stitching instead of straight stitching.

The stitch patterns that were studied (Reference 2) were

1. 1-, 2-, and 4-row straight stitch, Type 301
2. 1- and 2-row zigzag stitch, Type 304
3. 1- and 2-row double throw zigzag stitch, Type 308

Ten samples of each seam-stitch pattern combination were fabricated at eight stitches per inch using Kevlar FF thread and MIL-C-87156, Type II 2.25 oz/yd^2 Kevlar cloth. Two material control samples were taken from the same material area in an effort to minimize material variations. The samples were tested using the 1-inch grab method, and their seam efficiencies were calculated in accordance with Method 5110 for fabric seam efficiency perpendicular to the seam.

From the results of these tests, shown in Figures 1 through 5, it is readily seen that the overlap seam is very inefficient compared to the flat fell seam (as would be expected). Also, the wider the seam and the more rows of stitching, the stronger the stitch pattern, with the strongest stitch pattern being the flat fell with four rows of straight stitches at 70.3% efficiency. In comparison, a four-row Type 301 flat fell seam using MIL-C-7020, Type I nylon parachute canopy fabric and nylon E thread has an efficiency of 87% (Reference 3). In this case, Kevlar efficiency is approximately 80% that of nylon fabric.

A second stitch seam test was performed on 2.0 oz/yd^2 Kevlar cloth parallel to the seam. The seams were constructed, as shown in Figure 6, for straight stitch and single throw zigzag patterns 2.0, 4.0, 8.0, and 12.0 inches in length. The results in Figure 7 show the straight stitch efficiency to be very dependent on the stitch seam length and independent of the number of rows of stitches, while the single throw zigzag seam efficiency is essentially independent of both the number of rows of stitching and their length.

An interesting result of the seam efficiency tests parallel to the seam is that the straight stitch proves to be stronger than the zigzag stitch. This is exactly opposite to the experience of parachute designers. One possible explanation is that off-axis loading of the seam (a load not perpendicular to or parallel with the seam, but somewhere in between) causes each stitch of the straight stitch to be loaded almost one at a time. Another explanation is that the straight stitch seam efficiency decreases as the rate of loading increases because the thread does not have enough time to elongate to load the other stitches before it breaks. Thus the straight stitch "unzips" or rips out from one end to the other. However, because of the ability of the zigzag stitching to shift its orientation slightly, more stitches load up simultaneously. This results in the higher survivability of the zigzag over the straight stitch seen in parachute testing and everyday use.

WEBBING-TO-WEBBING SEAMS

Four types of webbing stitch patterns were tested using a simple webbing-webbing overlap seam structure on 1000-lb 2-inch-wide and 1500-lb 1-inch-wide Kevlar webbings:

1. Box stitch
2. Double W stitch
3. Diamond stitch
4. Horizontal diamond stitch

Ten samples of each stitch pattern were fabricated at eight stitches per inch for various seam lengths ranging from 1.25 to 4 inches. E and F thread was used for the 1000-lb webbing and for the 1500-lb webbing F, FF, and 3 cord. These are the thread sizes normally used for these weights of webbings. Two material controls were taken for every 10 stitch patterns fabricated. The samples were tested in accordance with Method 4108 and the seam efficiencies calculated in accordance with Method 5110.

Figures 8 through 11 show the seam efficiencies for the 1000-lb Kevlar webbing. The box stitch had the lowest seam efficiencies ranging from 68.3% to 88.2%, while the 5-point horizontal diamond had the highest seam efficiencies ranging from 90.9% to 100%. The 5-point diamond was almost as efficient, ranging from 75% to 100%. Most seams showed a significant improvement in efficiency as the seam length was increased. However, once the maximum efficiency for each stitch pattern was reached, no further increase in seam length caused any further improvement. This maximum efficiency length seems to be between 3 and 5 inches for the 1000-lb, 2-inch-wide webbing.

Figure 12 contains the only data for the 1500-lb 1-inch-wide webbing. The stitch pattern lengths ranged from 1.25 to 2.25 inches. Both the box stitch and the 3-point double W stitch patterns show a steady rise in seam efficiency, with no indication of the maximum seam efficiency limit being reached. The highest efficiency was achieved both for using F thread and a 2.25-inch-length seam, 60.7% for the box stitch and 62.6% for the 3-point double W stitch.

CORD-TO-CORD SEAMS

Three stitch seam patterns were tested using both 1000- and 3500-pound Kevlar cord:

1. Straight stitch
2. Single throw zigzag stitch
3. Double Chinese finger

The results are contained in Figures 13 through 15.

As would be expected, the double Chinese finger was the strongest cord-cord attachment method, with efficiencies ranging from 91.7% to 98.3%. The straight stitch with FF thread did reach a seam efficiency of 99.1% at a length of 16 inches for 1000-lb cord, but was only 15.7% for the 3500-lb cord. Perhaps the 3500-lb cord efficiency would have been better if 6-cord thread was used. The zigzag seam efficiency was fairly good for the 1000-lb cord, ranging roughly in order of seam length from 41% to 88.7%. As with the straight stitch, the 3500-lb cord efficiency was less. It ranged from 20.3% to 52.6% roughly in order of increasing seam length and thread strength. Three cord and 6 cord should do better.

CONCLUSIONS

The seam patterns that are very efficient with nylon parachute materials are also efficient with Kevlar; for example, the diamond stitch patterns and the double Chinese finger. The seam patterns that are inefficient with nylon are very inefficient with Kevlar; for example, the box stitch and overlap seams. The stitch patterns with fair to good efficiencies in nylon for Kevlar depend on their use, how they are loaded, their length, and the thread strength. Extreme care must be taken in choosing a stitch pattern for Kevlar materials because of its low elongation, poor flexural strength, and poor compression strength. Test it before you use it!

RECOMMENDATIONS

1. All government agencies and government contractors should (1) publish and make retrievable via computer database all future stitch pattern data for Kevlar, and (2) send a copy of the report containing the stitch pattern data (or the stitch pattern data itself) to the Textiles Engineering Branch, Aerosystems Department, Naval Weapons Center, China Lake, California. This will allow NWC to serve as a focal point for Kevlar stitch pattern data.

2. Kevlar seam and joint efficiencies should be tested to prevent the use of unexpectedly weak stitch seam joints.

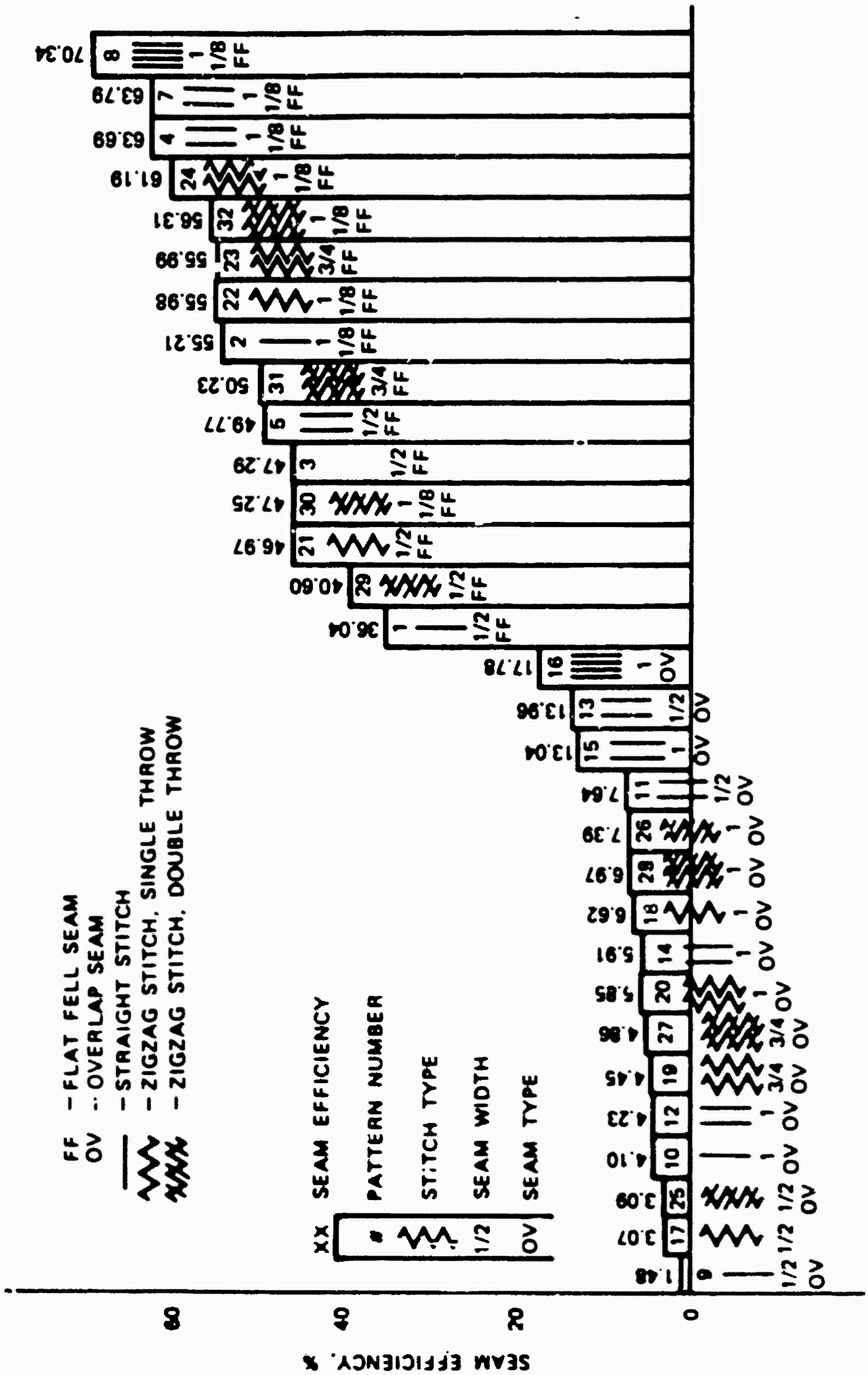


FIGURE 1. Kevlar Fabric Seam Efficiency for Flat Fell and Overlap Seams—1-Inch Grab Method.

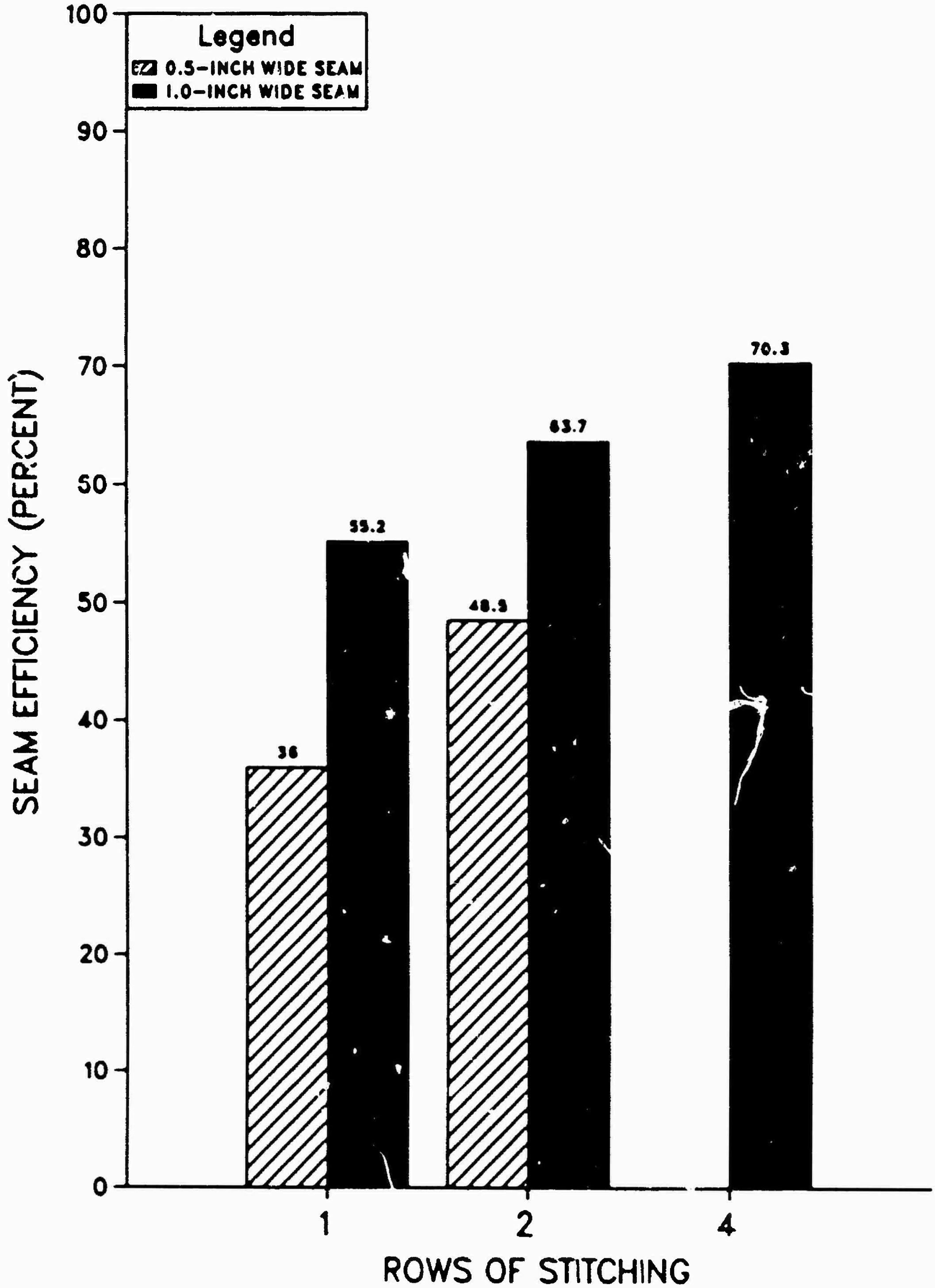


FIGURE 2. Straight Stitch Flat Fell Seam Efficiency MIL-C-87136, Type II Kevlar Cloth Perpendicular to Seam.

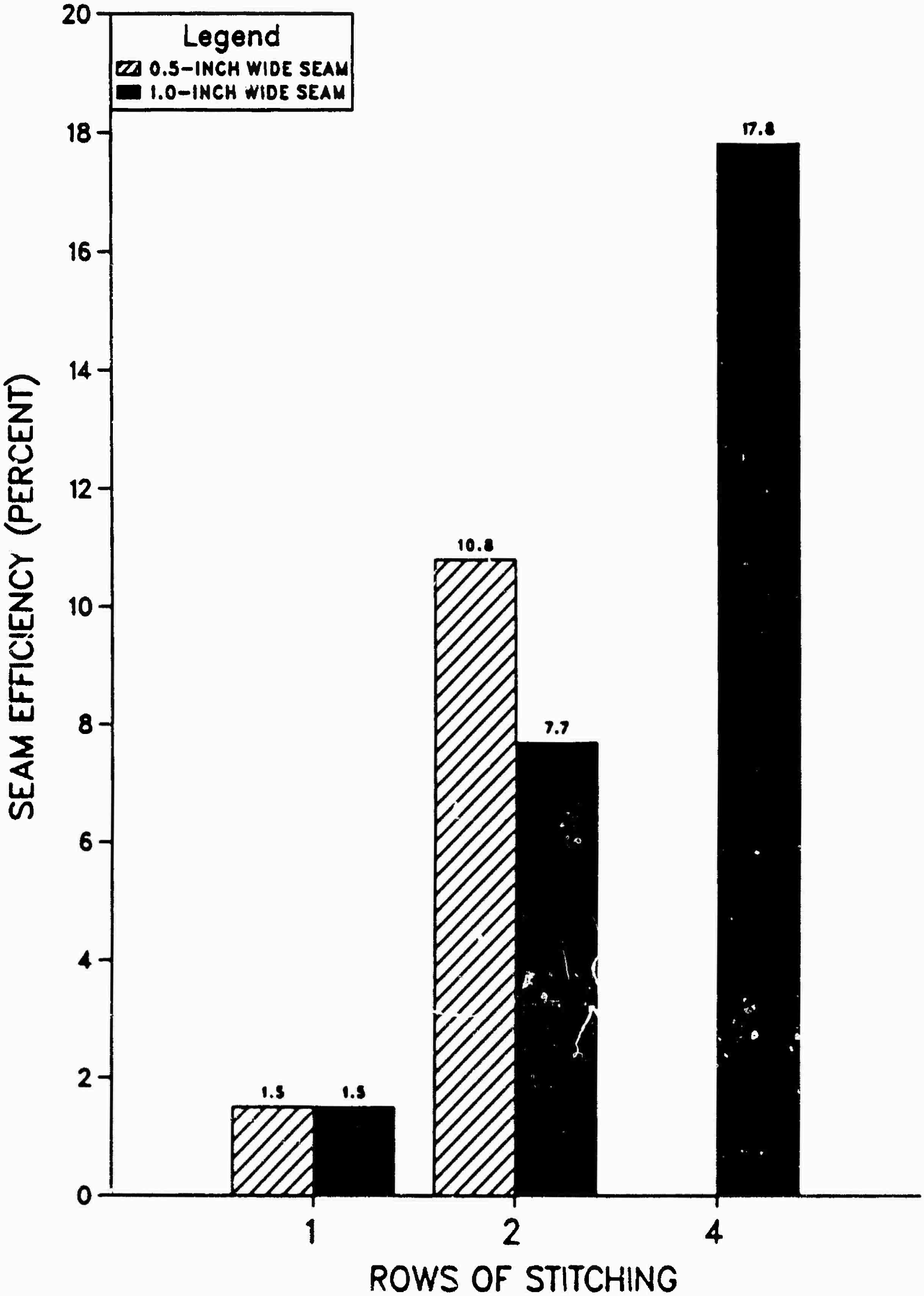
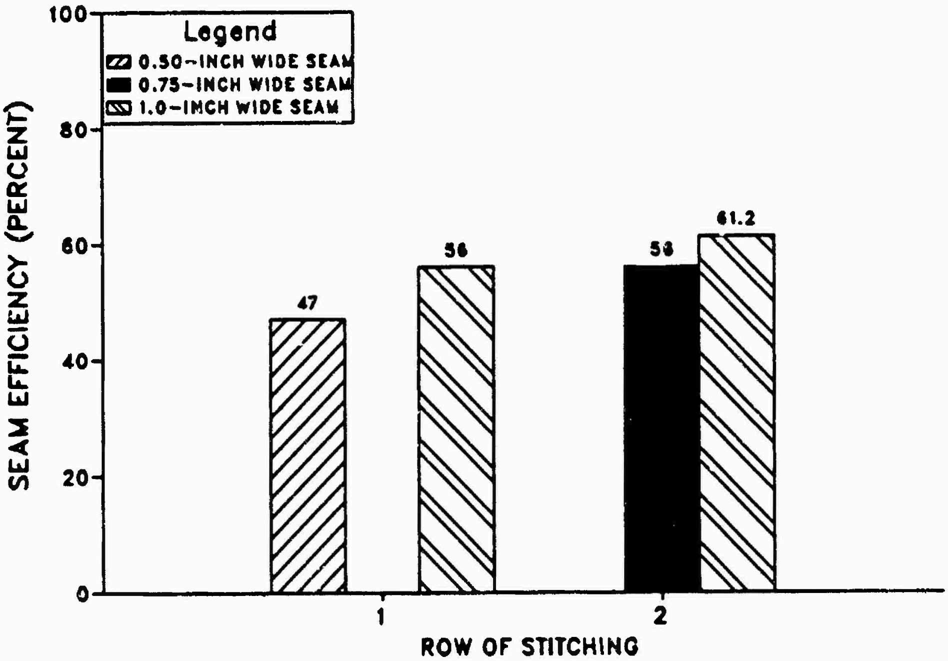
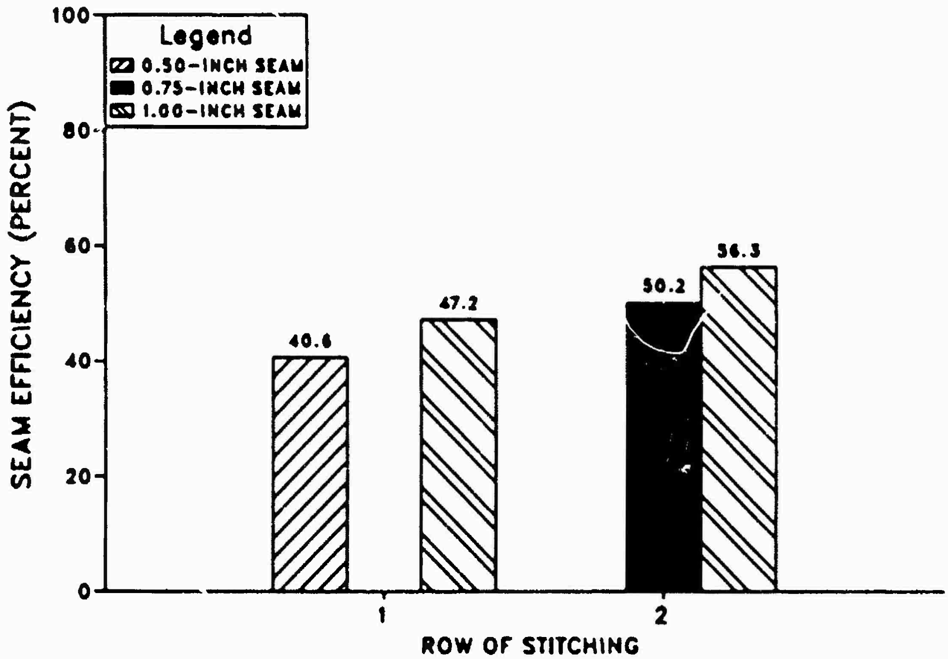


FIGURE 3. Straight Stitch Overlap Seam Efficiency MIL-C-87156, Type II Kevlar Cloth Perpendicular to Seam.

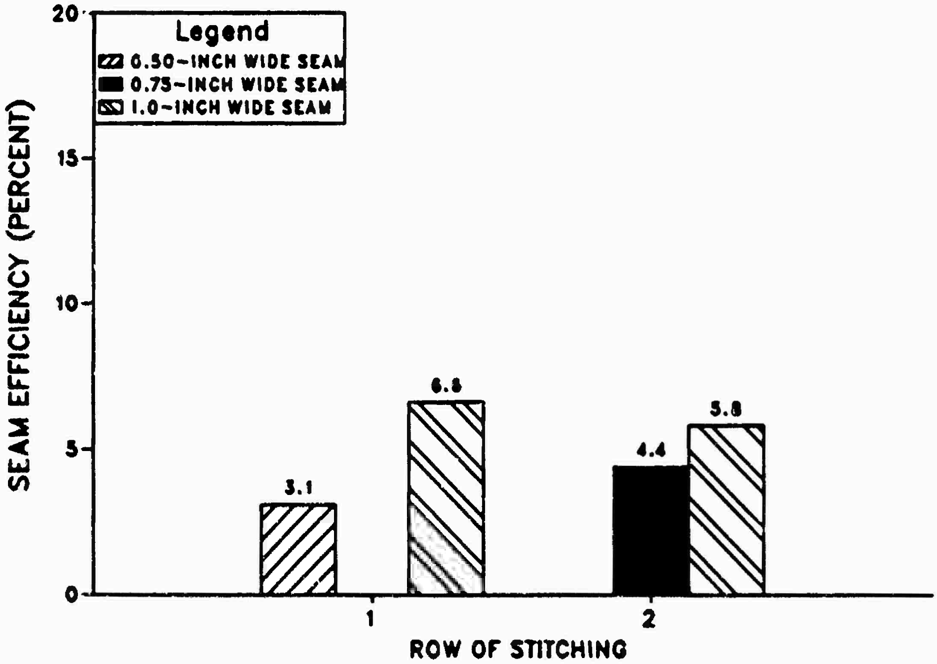


(a) Single throw.

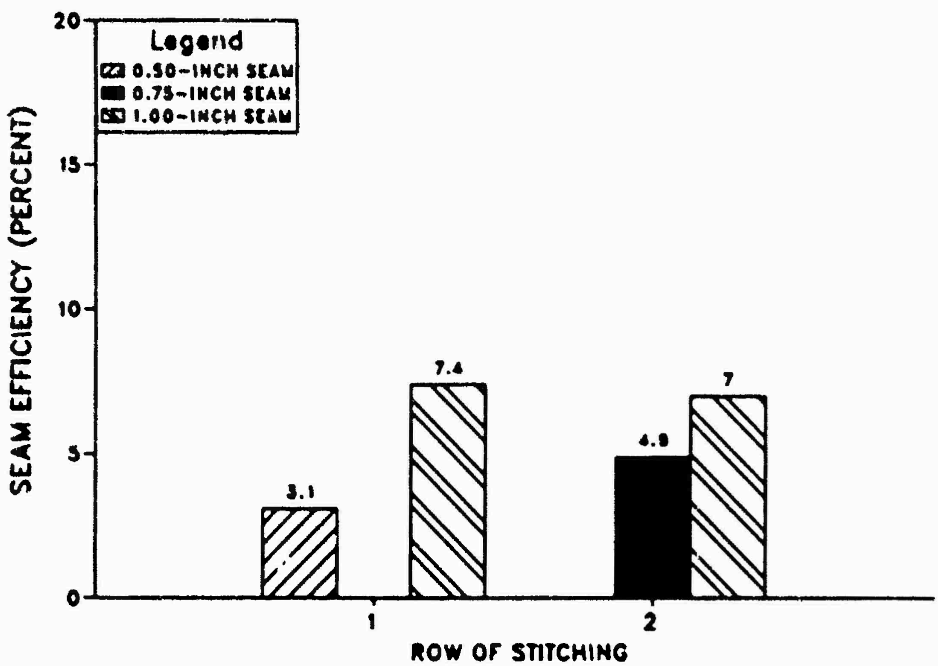


(b) Double throw.

FIGURE 4. Zigzag Stitch Flat Fell Seam Efficiency MIL-C-87156, Type II Kevlar Cloth Perpendicular to Seam.



(a) Single throw.



(b) Double throw.

FIGURE 5. Zigzag Stitch Overlap Seam Efficiency MIL-C-87156, Type II Kevlar Cloth Perpendicular to Seam.

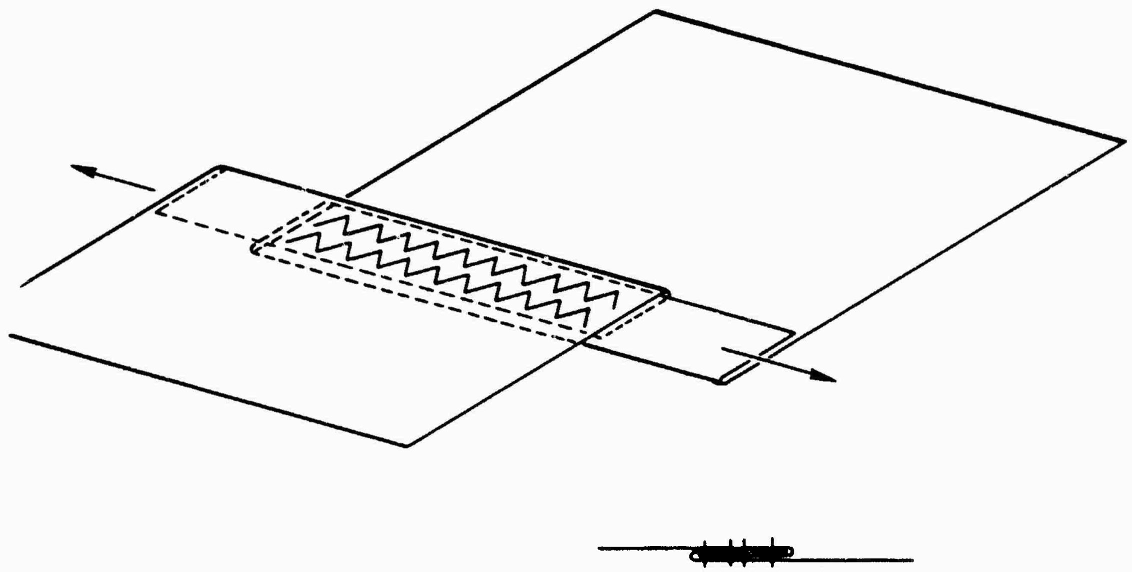
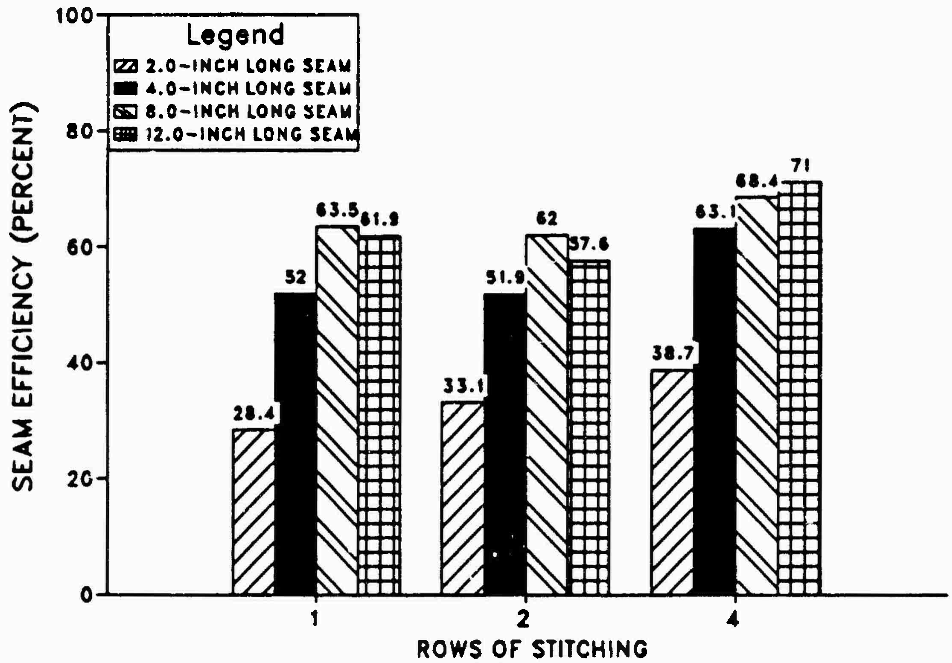
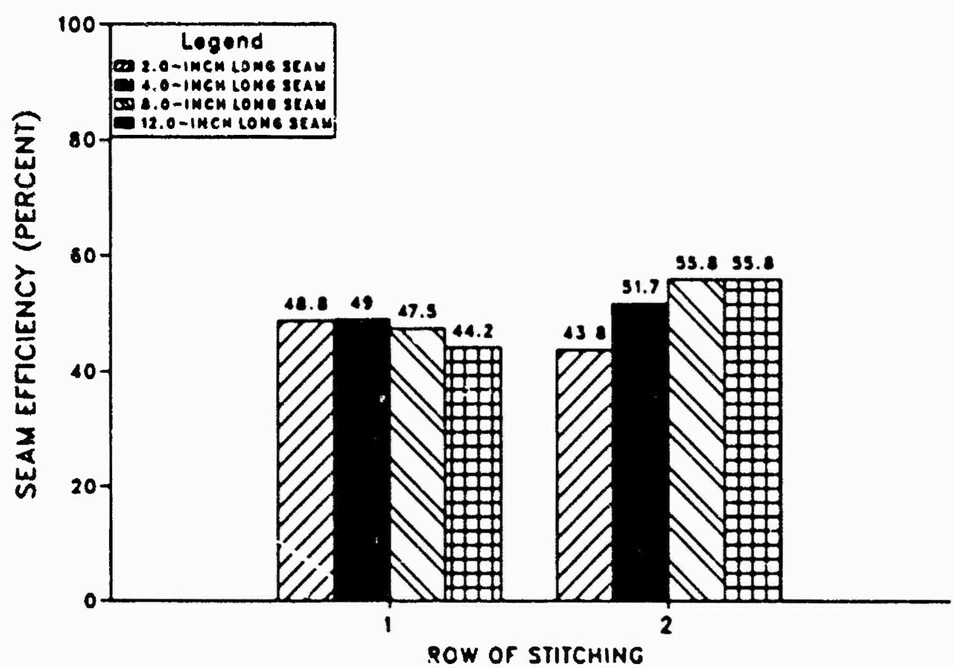


FIGURE 6. Sample Design for Along-the-Axis Seam Efficiency Test.

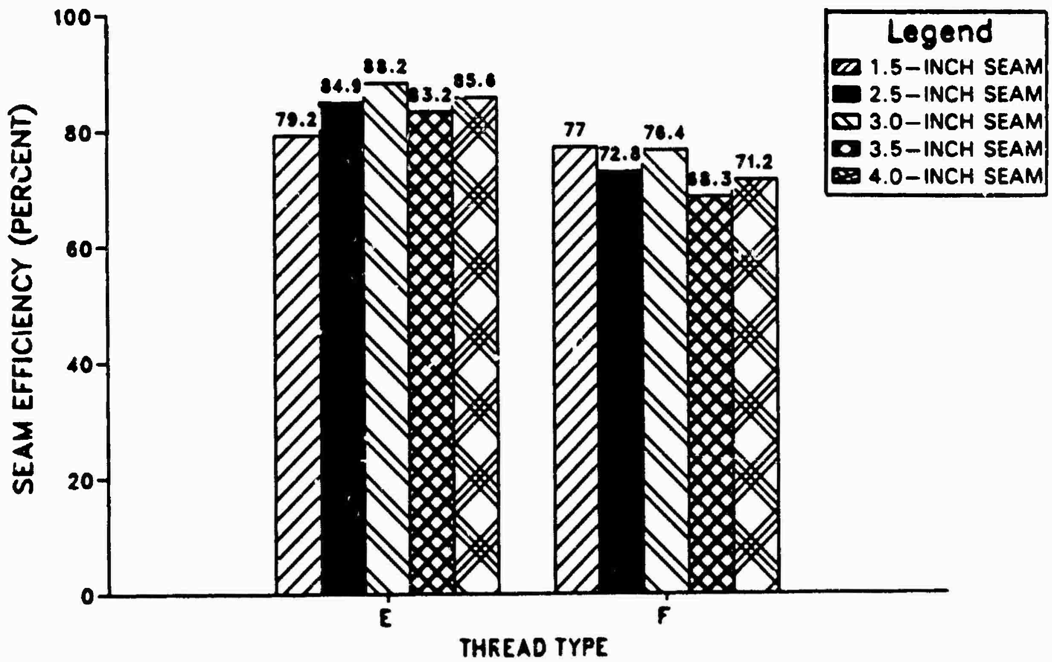


(a) Straight stitch.

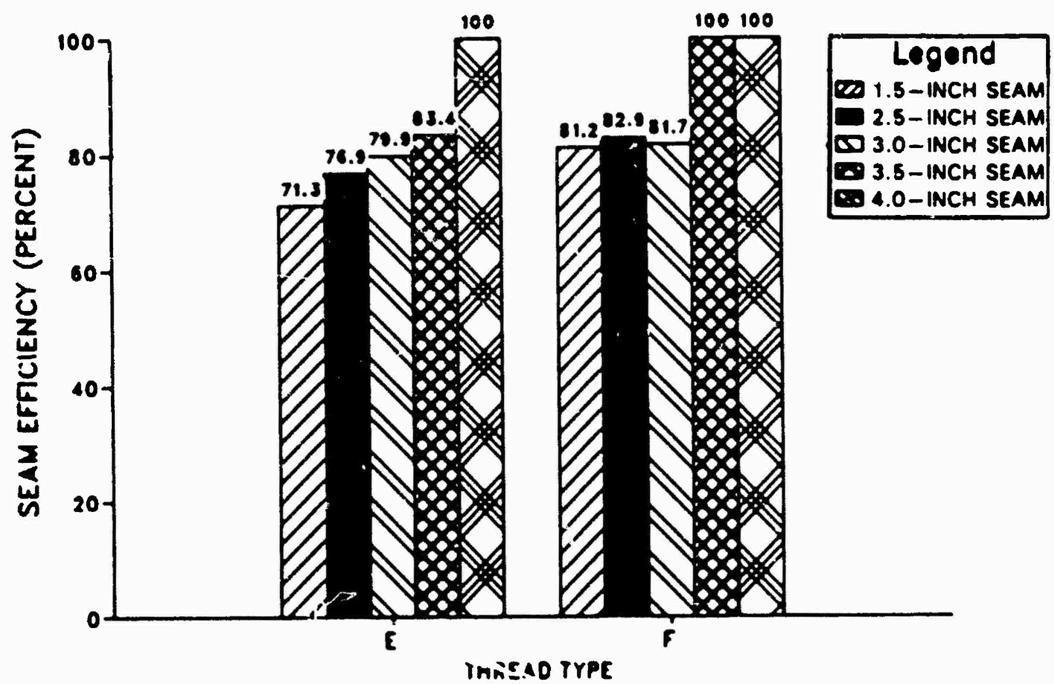


(b) Single throw zigzag stitch.

FIGURE 7. Flat Fell Seam Efficiency 2.0 oz/yd^2 Kevlar Cloth Parallel to Seam.

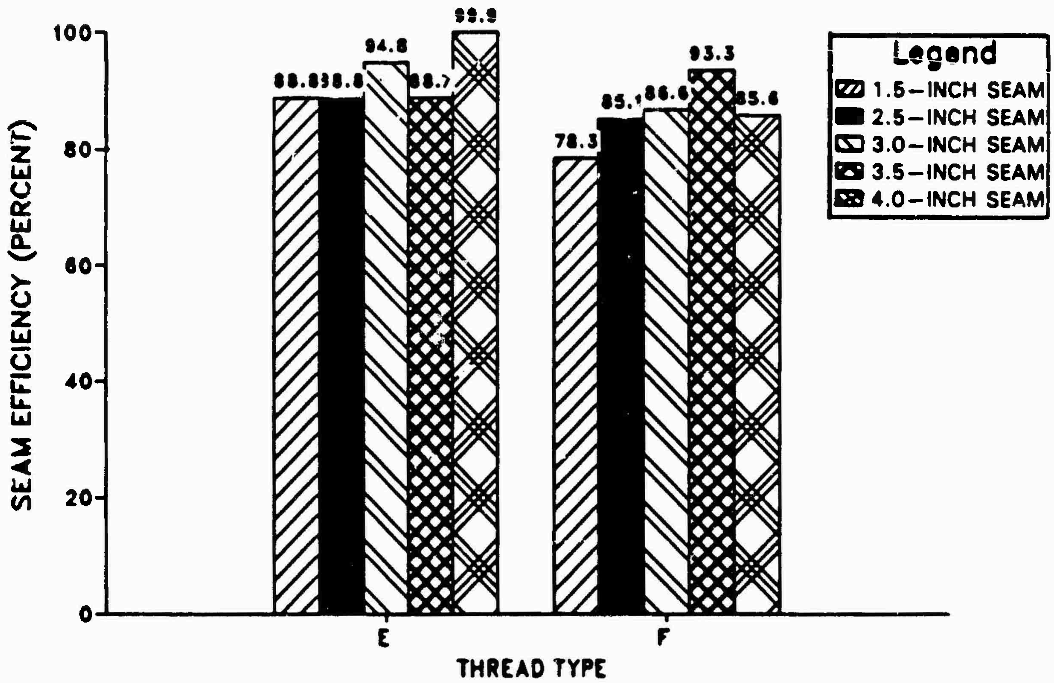


(a) Box stitch tape.

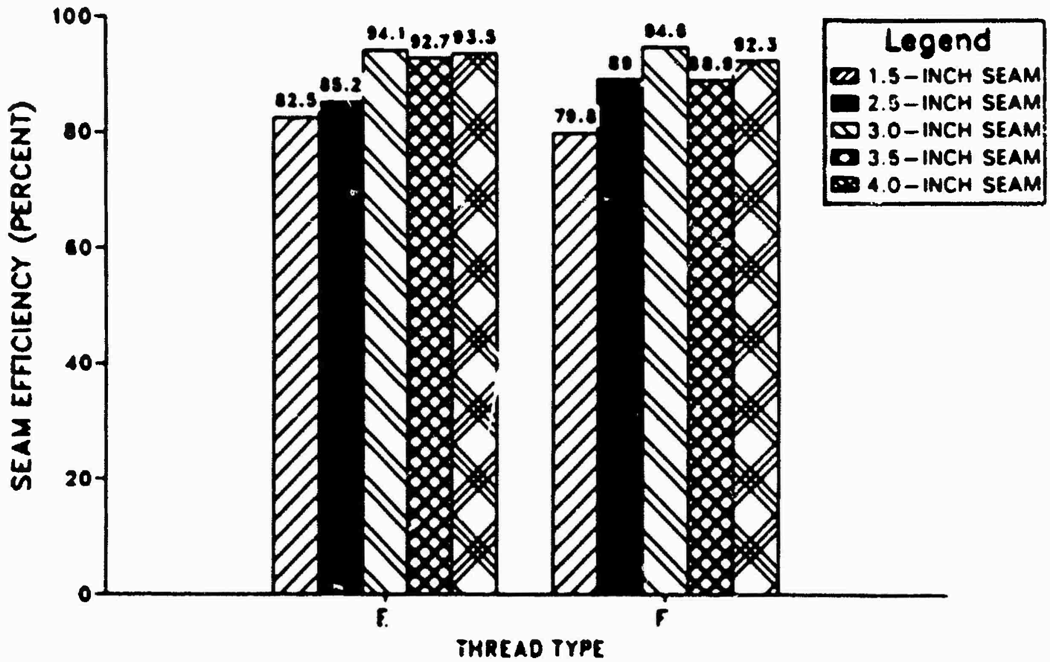


(b) 4-row double-throw zigzag stitch tape.

FIGURE 8. Tape Seam Efficiency MIL-T-87130, Type XI, Class 9A Kevlar Tape 1000-lb Break Strength.

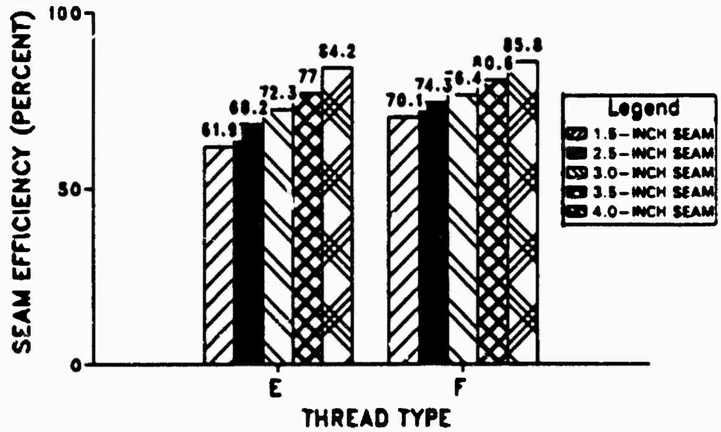


(a) 3-point double W stitch tape.

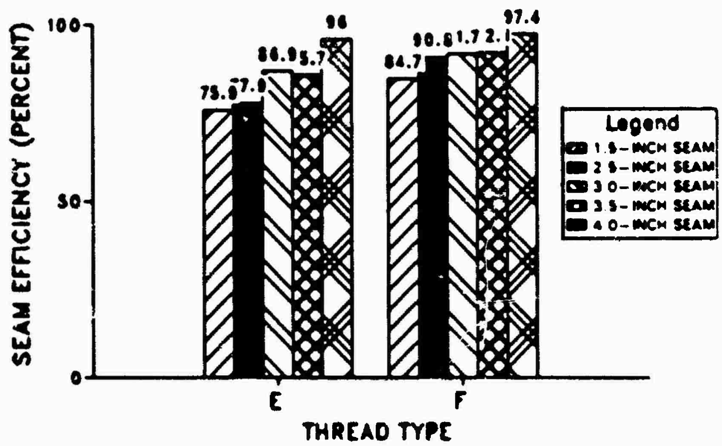


(b) 4-point double W stitch tape.

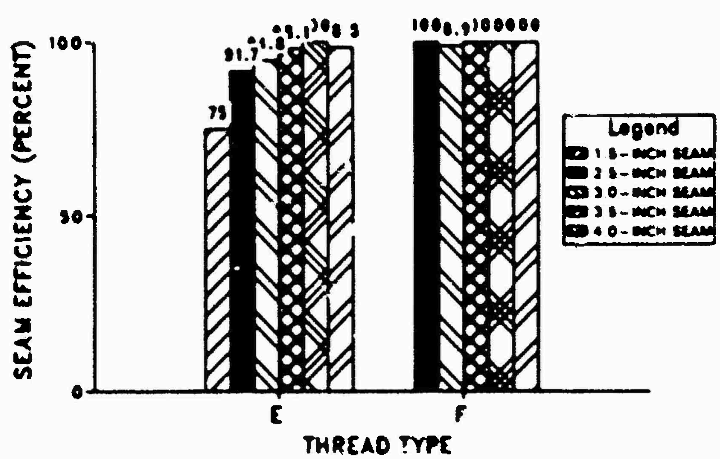
FIGURE 9. Tape Seam Efficiency MIL-T-87130, Type XI, Class 9A Kevlar Tape 1000-lb Break Strength.



(a) 3-point diamond stitch tape.

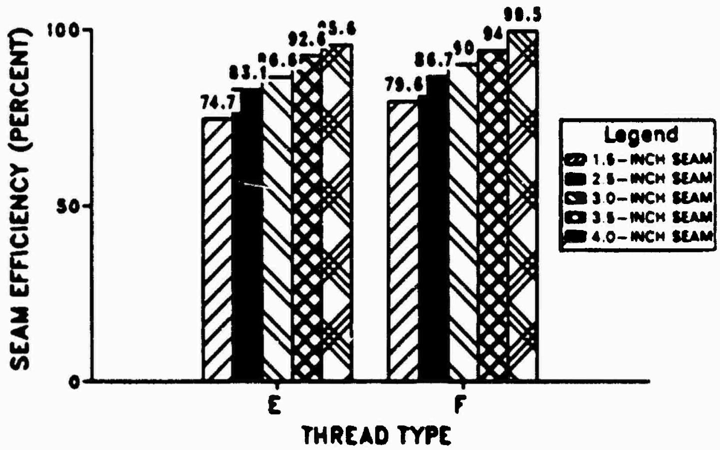


(b) 4-point diamond stitch tape.

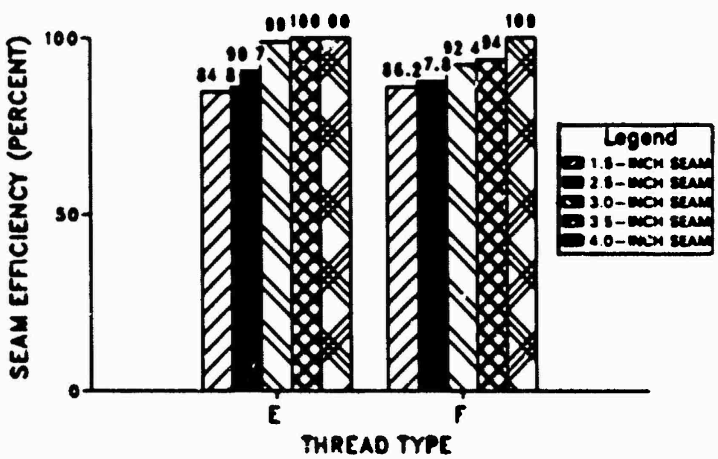


(c) 5-point diamond stitch tape.

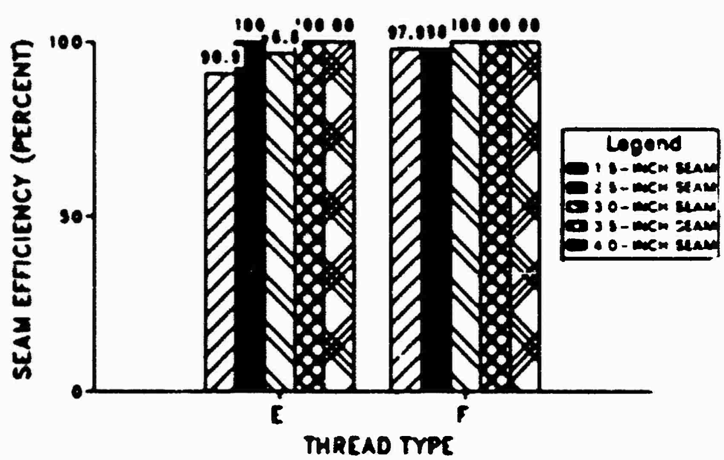
FIGURE 10. Tape Seam Efficiency MIL-T-87130, Type XI, Class 9A Kevlar Tape 1000-lb Break Strength.



(a) 3-point horizontal diamond stitch tape.

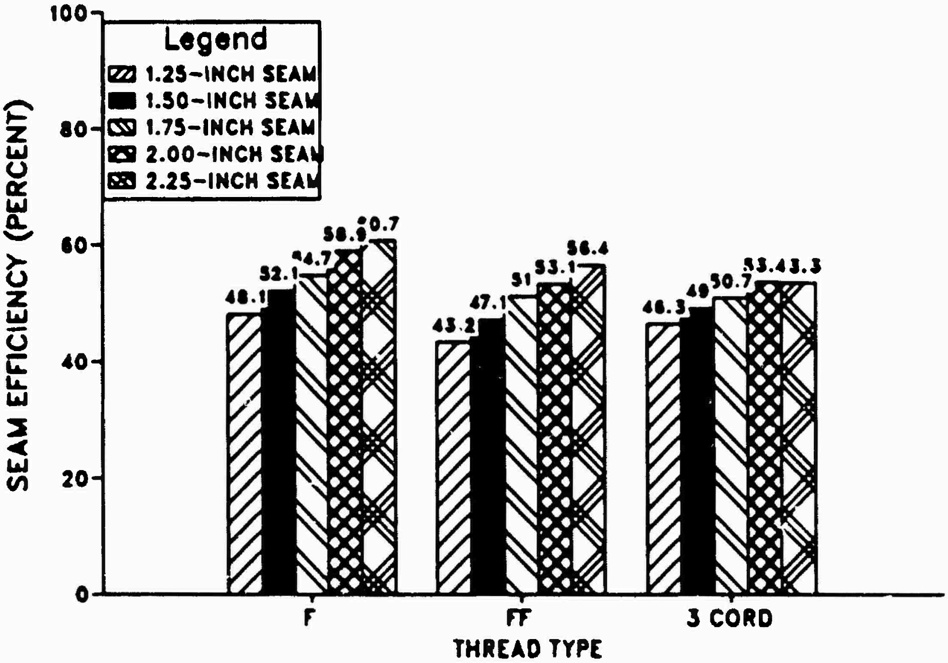


(b) 4-point horizontal diamond stitch tape.

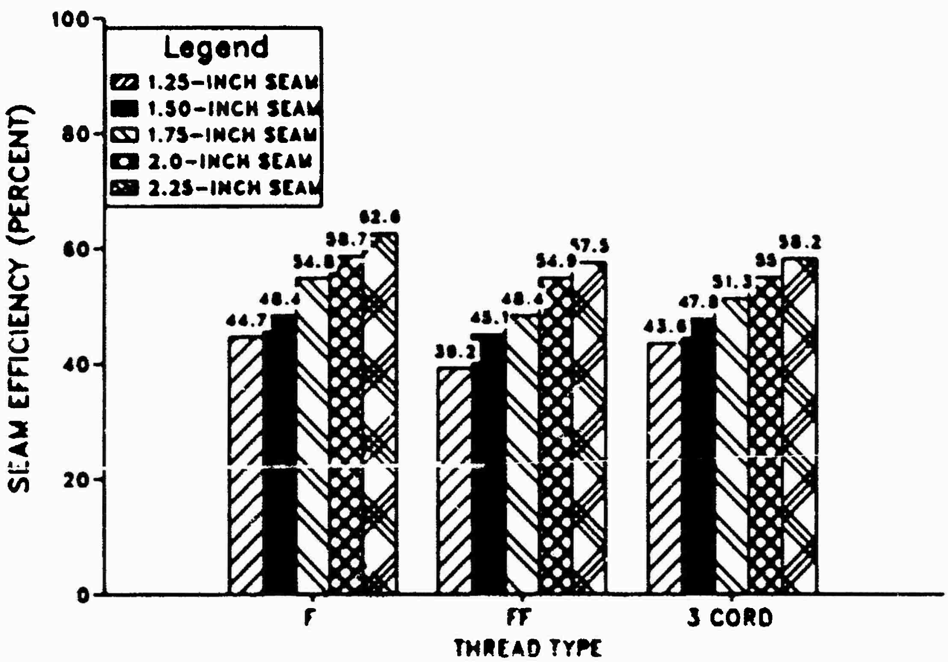


(c) 5-point horizontal diamond stitch tape.

FIGURE 11. Tape Seam Efficiency MIL-T-87130, Type XI, Class 9A Kevlar Tape 1000-lb Break Strength.

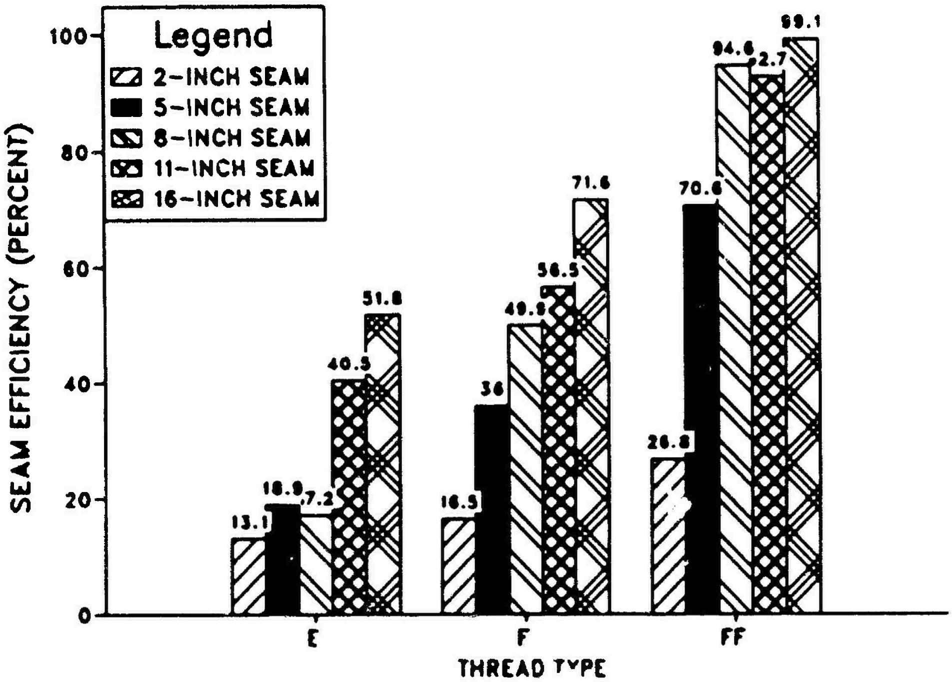


(a) Box stitch tape.

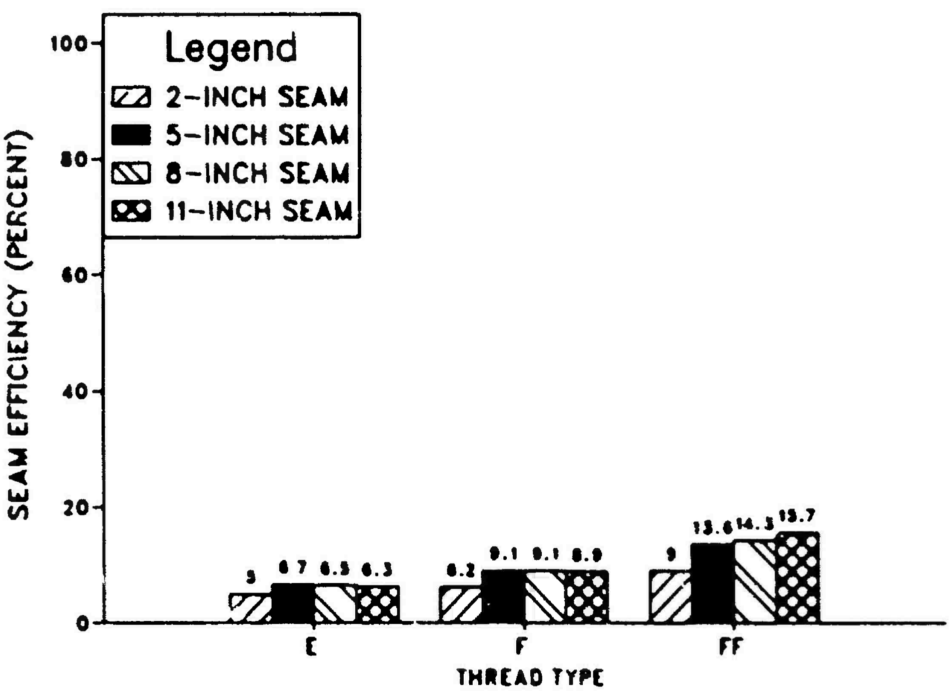


(b) 3-point double W stitch tape.

FIGURE 12. Tape Seam Efficiency MIL-T-87130, Type VI, Class 5 Kevlar Tape 1500-lb Break Strength.

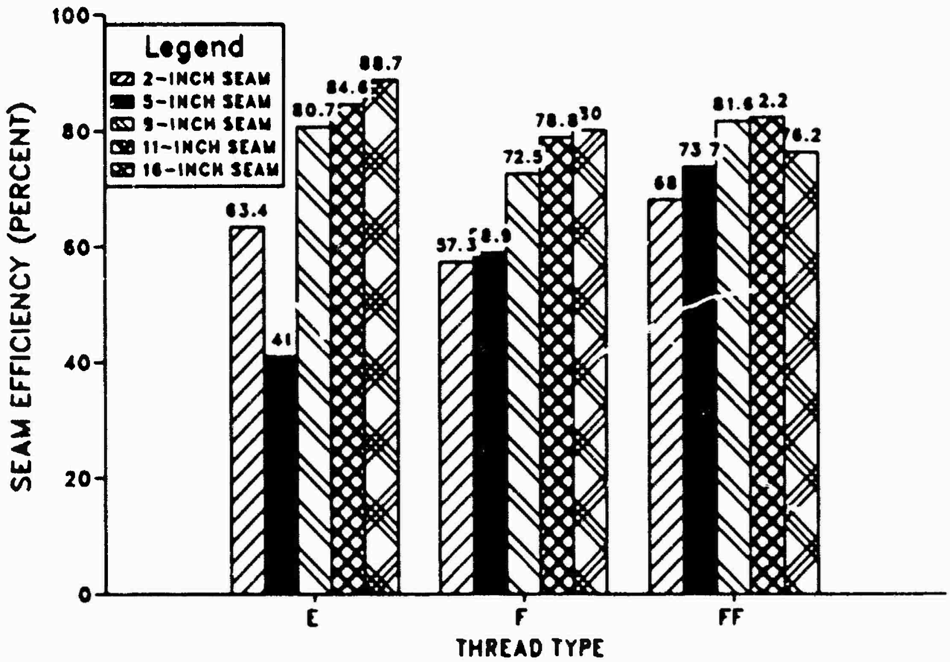


(a) Cord seam efficiency MIL-C-87129, type VII Kevlar cord 1000-lb break strength.

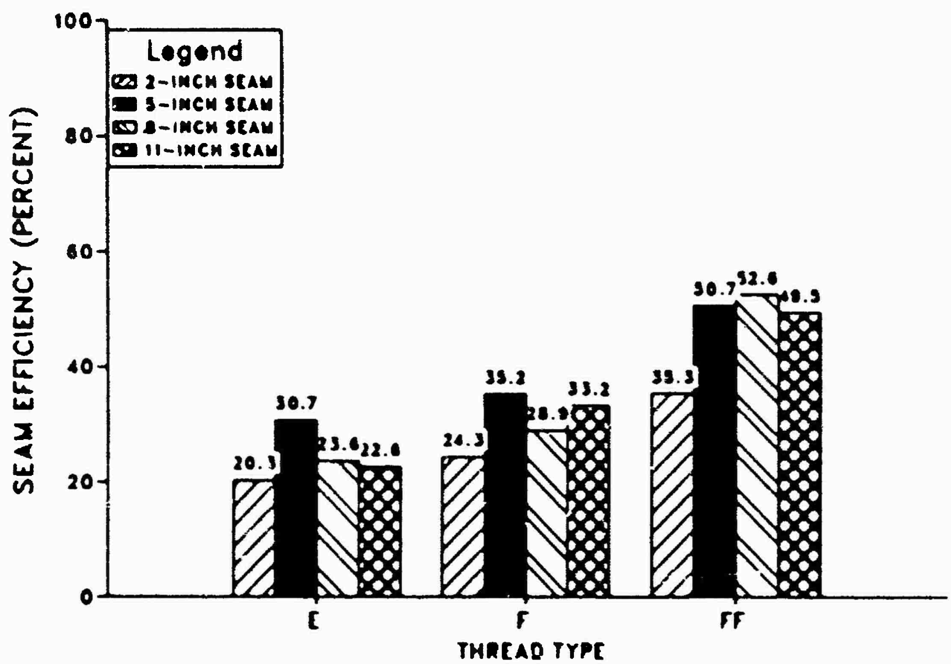


(b) Cord seam efficiency MIL-C-87129, type X Kevlar cord 3500-lb break strength.

FIGURE 13. Straight Stitch Cord.



(a) Cord seam efficiency MIL-C-87129, type VII Kevlar cord 1000-lb break strength.



(b) Cord seam efficiency MIL-C-87129, type X Kevlar cord 3500-lb break strength.

FIGURE 14. Zigzag Stitch Cord.

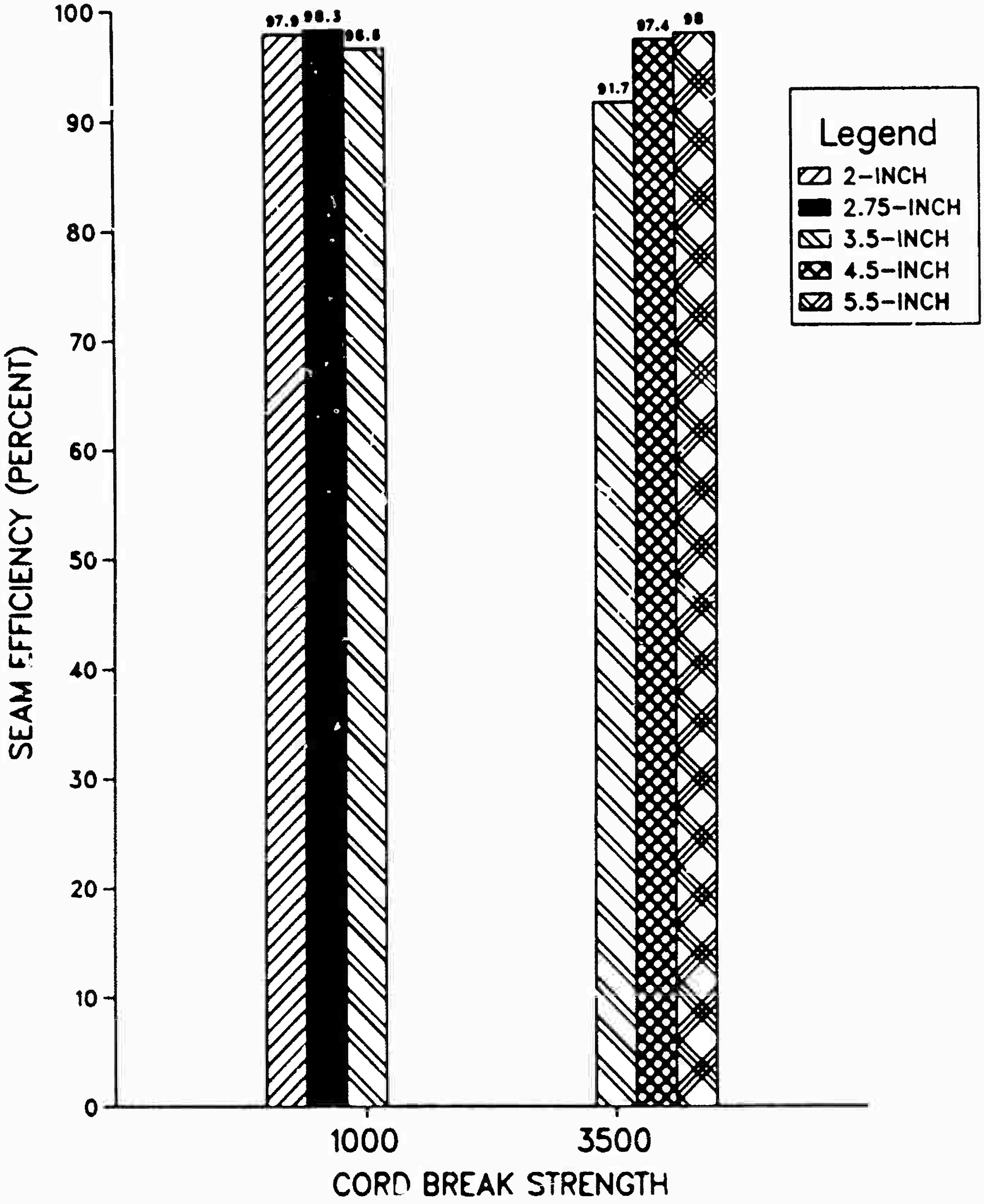


FIGURE 15. Double Ch... Finger Cord—Cord Seam Efficiency MIL-C-87129, Kevlar (...

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